

Approved for public release;
distribution unlimited.

AD 732853

DDC
RECEIVED
NOV 24 1971
B

DISTRIBUTION STATEMENT A

Approved for public release;

Distribution Unlimited

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

office of the chief of engineers

study on potential use of
industrialized building
for the department of the army

study summary: volume

1

**STUDY ON THE POTENTIAL USE OF INDUSTRIALIZED
BUILDING FOR THE DEPARTMENT OF THE ARMY**

VOLUME I: SUMMARY

By

**Cpt. D. Gordon Bagby
Dr. Robert M. Dinnat
Christopher A. Moyer**

August 1971

**Department of the Army
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
P. O. Box 4005
Champaign, Illinois 61820**

BLANK PAGE

OFFICE OF THE CHIEF OF ENGINEERS STUDY ON THE POTENTIAL USE OF INDUSTRIALIZED BUILDING FOR THE DEPARTMENT OF THE ARMY

OBJECTIVES

The Office of the Chief of Engineers (OCE) directed the Construction Engineering Research Laboratory (CERL) to investigate how industrialized building could be applied advantageously in the U. S. Army's military construction program.

This Directive included six principal objectives:

1. To provide background information on the history, characteristics and direction of industrialized building;
2. To measure the present capabilities of the industrialized building industry and assess its probable response to programmed military construction;
3. To identify industrialized building systems suitable for employment in the Army's military construction program;
4. To suggest locations most amenable to industrialized building;
5. To identify and discuss possible procurement and implementation procedures; and
6. To provide comparisons between conventional and industrialized construction costs and construction durations.

STUDY PROCEDURES

The primary source of information developed to meet these objectives was a mail survey conducted during the period March 15 to May 15 of 664 industrialized building firms; 47 percent responded. Each firm was queried on its ability to provide a feasible industrialized building alternative to conventional building. To be a feasible alternative the firm's product had to be design compatible, production compatible and procurement compatible with current criteria and policies—controls which have been established for conventional building.

Design compatibility was determined by matching the building characteristics of a firm's product against DOD construction standards; a complete match yielded design compatibility.

Production compatibility was determined by matching the firm's market aggregation requirements for its industrialized building system against the market characteristics of DOD's building program in FY 73-77. Procurement compatibility was determined by comparing a firm's stated required contracting procedures with procedures permitted under existing Armed Services Procurement Regulations.

Using these criteria, each firm's product was classified as a feasible or an infeasible alternative to conventional as portrayed in Figure 1. If the firm's product was design, production and procurement feasible, the product was classified as a feasible alternate; if it was deficient in any of these respects, the firm's product was infeasible.

DESIGN COMPATIBILITY

During the initial phase of the study, industrialized builders were surveyed to obtain information on the design and performance characteristics of their products.

Concomitant with this effort, the Army's military construction program was analyzed to identify buildings amenable to the employment of industrialized methods. Six building types—constituting 53 percent of the dollar value of the FY 73-77 construction program were selected. Namely,

1. Enlisted Men's Barracks
2. Bachelor Officer's Quarters
3. Administrative Buildings
4. Covered Storage Facilities (Warehouses)
5. Tank and Automotive Maintenance Facilities
6. Classroom Type Training Facilities.

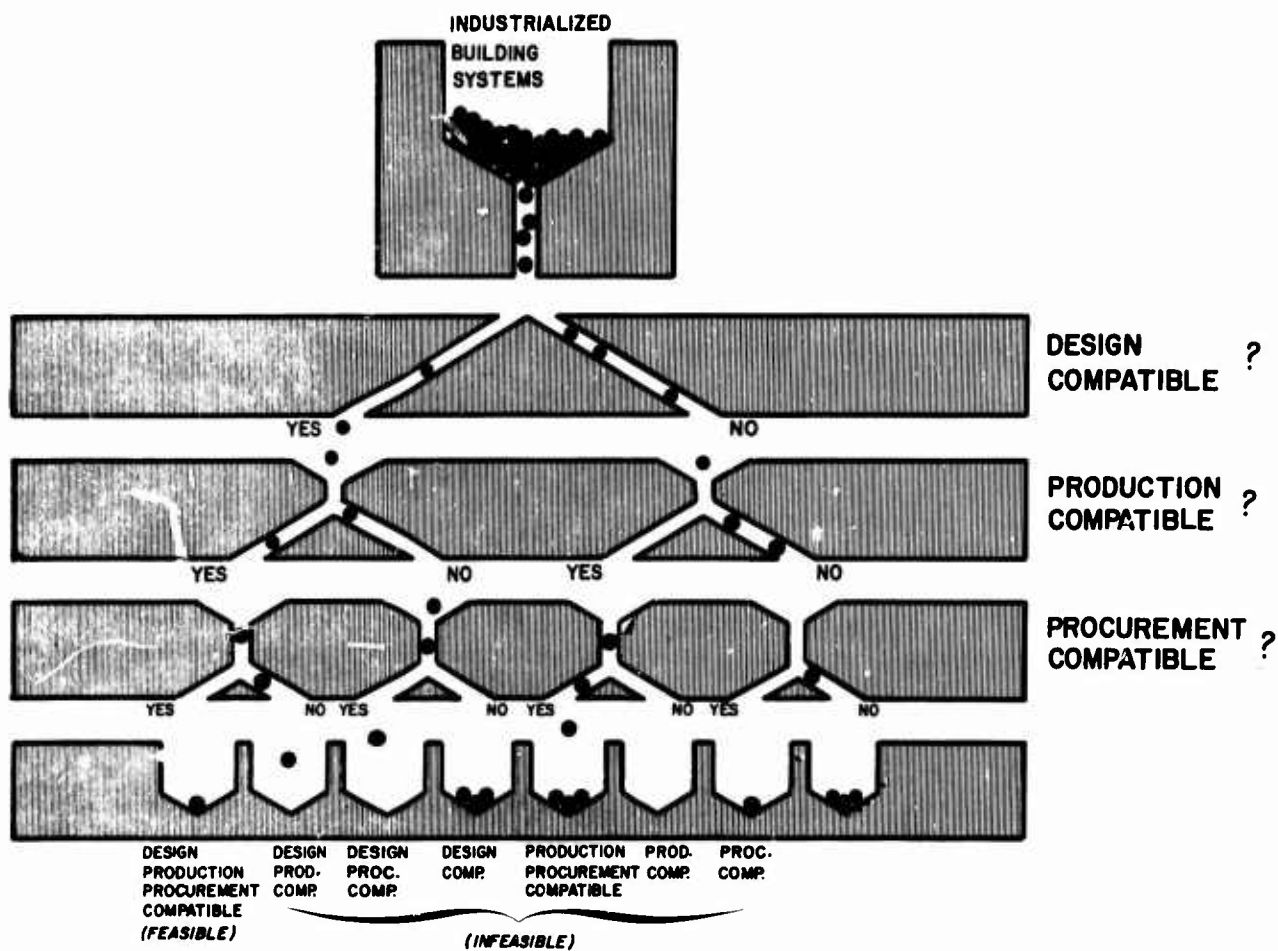


FIGURE 1

The constituent parts of each major building type were identified and aligned with corresponding industrialized subsystem elements. Each subsystem was then subdivided into elements and characteristics for which design requirements were considered necessary. The elements and characteristics governed by the DOD criteria were identified. For elements and characteristics not governed by the DOD criteria performance, standards were developed from:

1. requirements of nationally-recognized code authorities, trade associations and professional societies;
2. results of similar private and public studies, conducted for similar purposes for similar building types;
3. minimum standards for Federally-financed housing;
4. current technological and production capability of private industry; and
5. the professional judgment of industry consultants.*

The questionnaire information was matched against these criteria to establish design compatibility. These criteria were compared to the levels of performance that each manufacturer stated for his product, system or subsystem on such performance characteristics as fire resistance ratings, flame spread ratings, live loads, construction classifications, sound transmission class ratings, etc.

The information generated on each firm's product in the design compatibility classification process was:

1. The name of the firm evaluated, together with an assigned identification number;
2. Those DOD criteria with which the firm's product complied.
3. Those DOD criteria with which the firm's product did not comply.
4. Those DOD criteria on which a judgment could not be made due to partial completion of the particular portion of the questionnaire by the firm.
5. Those DOD criteria which did not apply to the firm's product.

An example of an entry in the design compatibility process is:

I. D. Number: 101
Firm Name: WXYZ Corporation, Inc.
Complies (DOD): 10,11,12,13,14,20,21, 30**
Non-Compliance (DOD): None
Not Judgeable (DOD): 40,50
Not Applicable: 60,70,80,90

These comparisons suggested that 31 industrialized builders, or 11.5 percent of all respondents, could provide all 6 building types in any region of the nation under current Department of Defense Design Criteria.

A histogram describing the DOD construction criteria provisions violated most frequently by non-qualifying firms is shown in Figure 2.

As the diagram illustrates, standards pertaining to specific climatic regions or particular types of buildings eliminated disproportionate numbers of candidate firms. Hence, a larger number of industrialized builders would prove Design Compatible if restricted as to building type or geographical region.

Indeed, 101 firms, or 37.4 percent of all industrialized builders responding to the Survey, were design compatible for at least one building type in at least one geographical region of the United States.

*The performance standards were developed for CERL by the Engineers Collaborative, Ltd.

**Code numbers correspond to requirements found in the DOD Construction Criteria Manual.

NON-COMPLIANCE FREQUENCY DOD CONSTRUCTION CRITERIA

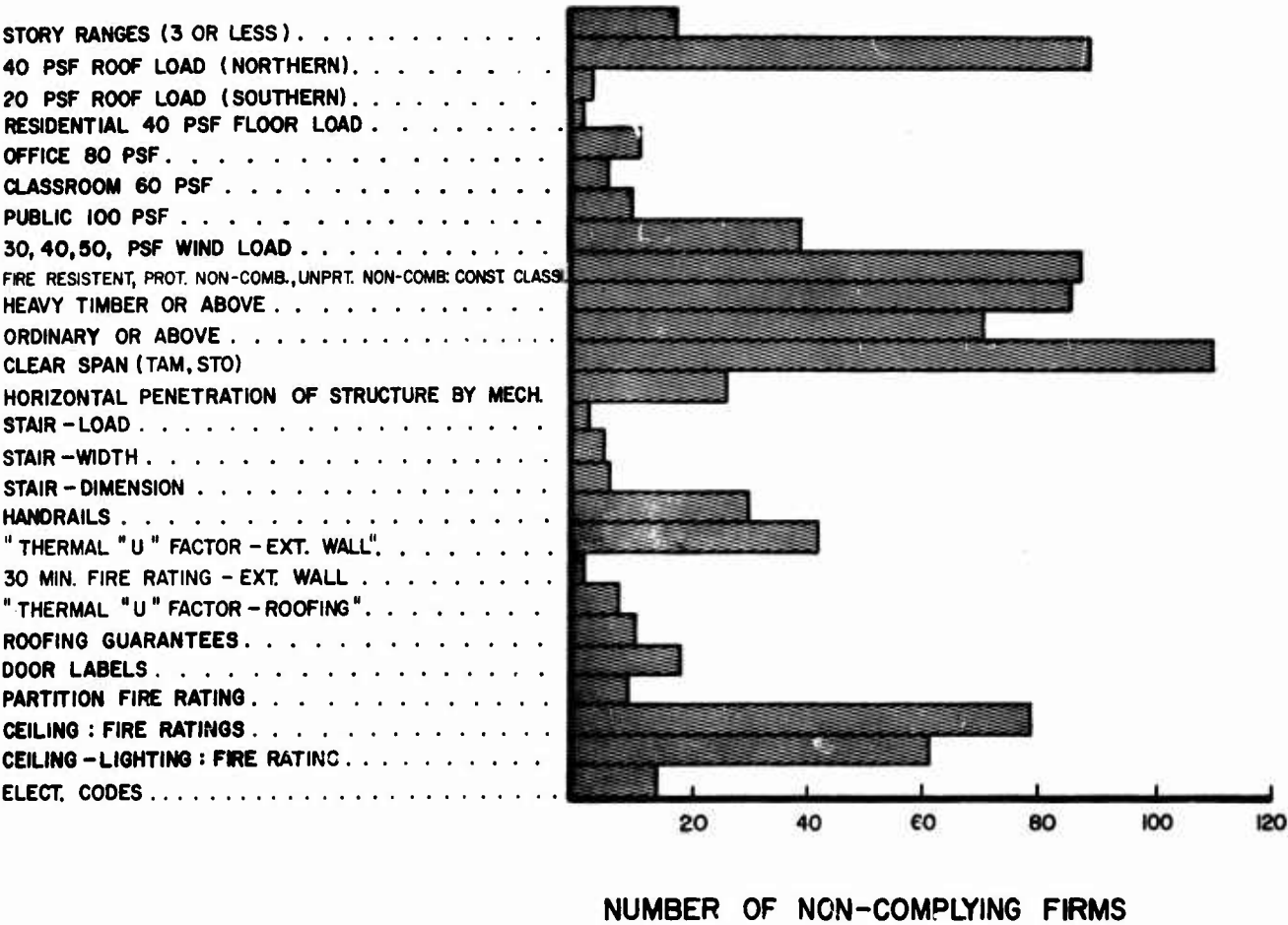


FIGURE 2

PRODUCTION COMPATIBILITY

The production capability of each firm was determined by the following procedure:

1. Each firm was categorized by the degree to which it provided a complete building system. Only those manufacturers providing a building enclosure were given further consideration, since the possibility of successful procurement requires the availability of at least one design-compatible structural subsystem.
2. The minimum dollar volume to justify a production run for each firm was then identified from questionnaire responses.
3. The dollar value and area of planned building construction for FY 73-77 were obtained from reports issued by the Army, Navy and Air Force. Groupings of similar buildings were made and aggregated into the 82 circular zones of 50 mile radius as shown in Figure 3. Each zone contains at least one Armed Services installation with planned construction of a facility in one or more of the six major building types in FY 73-77. Wherever possible an Army installation was made the center of the zone (the fifty mile radius is approximate as a few installations as far as seventy miles from a zone center are considered part of the zone). In 37 of the zones no Army installations exist which plan construction in one of the six major types in FY 73-77.

A firm was adjudged production compatible if the minimum dollar production volume of the firm was less than the aggregated military construction program in zones lying within the firm's economical transportation distance. These comparisons between firm market areas and the geographical distribution of FY 73 projects provided a basis for future selection of prototype projects. Similar comparisons with projected five year programs suggested possible modifications to the Army's five-year building program to increase the opportunities for advantageous use of industrialized building systems.

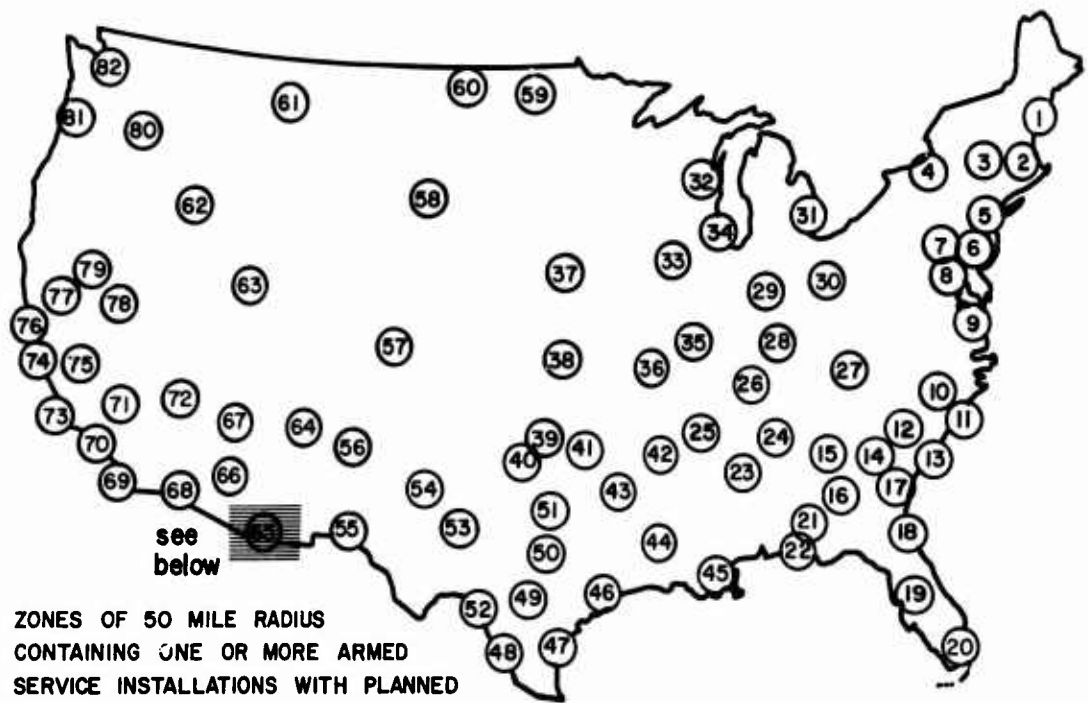
The incipient character of the industrialized building industry emerged during this phase of the analysis. While 88.7 percent of the firms responding to the survey were now in full production, 35 percent of these firms commenced production subsequent to 1968. 61 percent of the firms grossed less than \$5 million per year; 30.7 percent earned less than \$1 million per year. No industrialized building firm claimed to have nation-wide marketing capabilities.

PROCUREMENT COMPATIBILITY

An industrialized building firm was considered to be procurement compatible if it would offer its service(s) and/or product(s) directly to the Army and if at least one of the ways it would offer them was permitted by Federal procurement procedures. The primary question to be answered, was "Could a firm's industrialized product be purchased under present procurement regulations?"

Emerging associations or contractual relationships of professional design, management and manufacturing firms were also explored to determine the effect of Government procurement procedures on the accommodation of these new organizational-forms in the building industry. The procurement methods established by the Armed Services Procurement Regulations and those utilized by industry provided a basis for comparison and subsequent determination of compatibility. The methods by which firms were willing to offer their services and/or products for procurement were obtained by questionnaire. The firms were questioned about their willingness to accept Army-permitted methods as well as other known methods.

A firm was classified procurement compatible if they would sell directly to the owner and would utilize procurement procedures deemed acceptable by the Armed Services Procurement Regulations. On the basis of this criteria 25 percent of all respondent firms were procurement compatible.



ZONES OF 50 MILE RADIUS
CONTAINING ONE OR MORE ARMED
SERVICE INSTALLATIONS WITH PLANNED
CONSTRUCTION IN ONE OF SIX BUILDING
TYPES.

FY 73-77

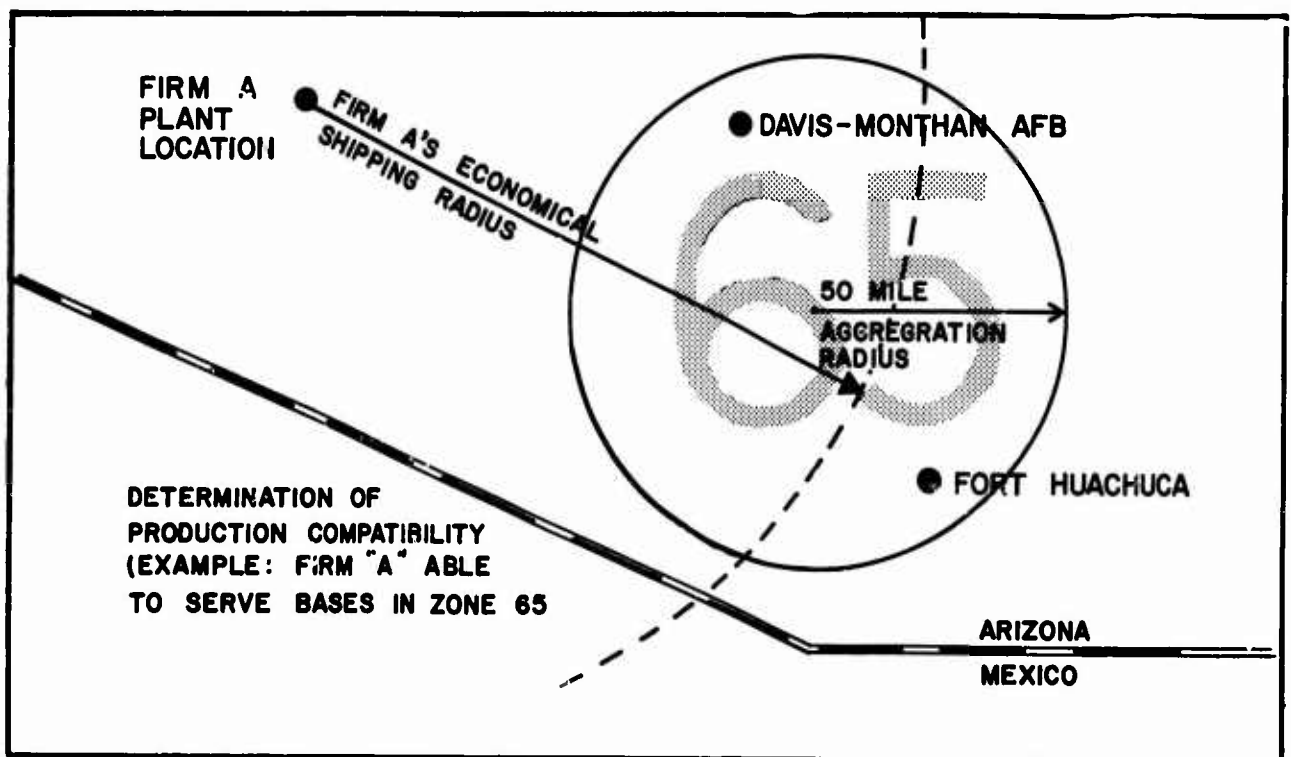


FIGURE 3

FEASIBLE ALTERNATES

On the basis of the design, production and procurement capability of each respondent firm, its product was classified into one of eight mutually exclusive categories:

1. Design, production and procurement compatible.
2. Design and procurement compatible but not production compatible;
3. Design and production compatible, but not procurement compatible;
4. Design compatible, but not procurement or production compatible;
5. Production and procurement compatible, but not design compatible;
6. Production compatible, but not procurement or design compatible;
7. Procurement compatible, but not production or design compatible; and
8. Not design, production, or procurement compatible.

24 firms within the continental United States evidenced the requisite production design, procurement policies, and production capacities to qualify for FY 73-77 Army building construction programs. An additional 25 firms were conditionally feasible.* The geographical areas served by each of these firms in Category 1 is summarized in Figures 4 and 5. Categories 2, 3, 4, 5, 6, 7 and 8 contained 9, 41, 7, 36, 79 and 66 firms respectively.

DOD BUILDING PROGRAM FEASIBILITY

The 49 firms that yielded products that were design-production-procurement compatible, (i.e., yielded feasible alternates) provided a basis for the identification of those portions of the Fiscal Year 1973 programmed construction plans which were most likely to be amenable to the use of industrialized building systems. Figure 4 delineates all geographical regions served with one or more of the 49 industrialized building systems which are feasible alternates to conventional construction. Assuming that competition among industrialized building firms would yield commensurate reductions in total building costs, this diagram suggests that Midwest and Mid-Atlantic military installations could be economically provided with feasible industrialized building systems in the FY 73 program. Some of the installations located in these regions include Fort Benjamin Harrison, Fort Knox, Edge-Arsenal, Fort Meade, Vint Hill Farms, Fort Belvoir, Fort Meyer, Fort McNair, Andrews Air Force Base, Fort Detrick, etc.

This finding is not significantly altered when recast in terms of a five-year MCA construction program. Figure 5, for example, suggests that several additional geographical areas could be served by these same feasible industrialized building firms if projected appropriations for a five year period were awarded in lump sum packages. However, the same regions manifesting a superiority in the FY 73 comparisons again reemerge in the intermediate range appropriations schedule.

Improving DOD Market for Industrialized Builders: Market Aggregation

Such a finding suggests that some form of market aggregation would be required to increase the potential of industrialized building for military installations in the Southern and Western regions of the United States. One potential method would be to change the scheduling of projected installation improvements to increase market aggregation. Another possibility might be to simply aggregate all Army, Navy and Air Force facility needs in proximate installations. Still a third approach to increasing market aggregation would be the joint production of structures for both civilian and military markets.

An effort was made by CERL to ascertain the feasibility of this third alternative.

Specifically, CERL attempted to:

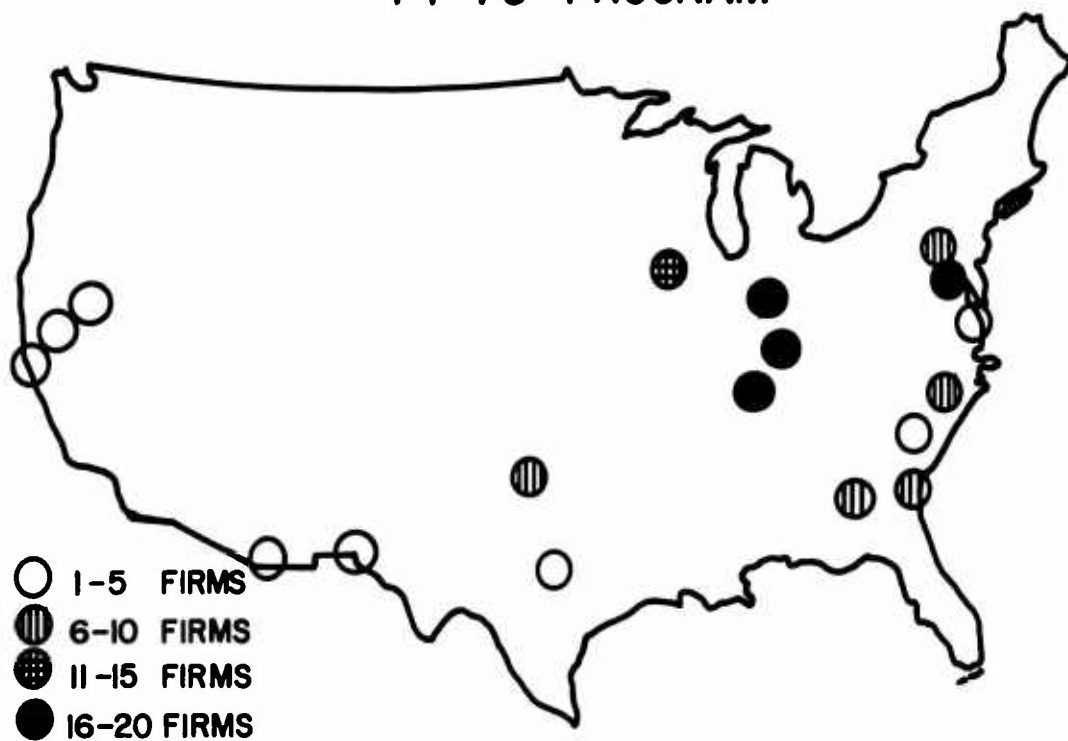
1. identify buildings procured by non-military federal, state and local agencies which are similar to facilities required on U. S. Military Installations;
2. determine the programmed construction of these representative building types; and
3. identify and project the demand for similar facilities arising in state and local governments, etc., within the next five years (1971-1976).

The building construction programs of thirty public agencies within a fifty mile radius of four Class-I Army Installations; Fort Belvoir, Fort Benning, Fort Knox, and Fort Ord were reviewed. (See Figure 6.) It was concluded that the demand for non-military public buildings similar in function to facilities required on U. S. Military Installations is both recognizable and programmatically acceptable to a limited degree. Although a considerable need for the education and persuasion of public officials with regard to industrialized buildings is required, the effort to establish consortiums for the mass purchasing of industrialized building components appears to be feasible. (Although Congressional approval may be required.)

*That is to say, feasible only for particular building types in certain restricted climatic regions of the United States.

FIGURE 4

FY 73 PROGRAM



FY 73-77 PROGRAM

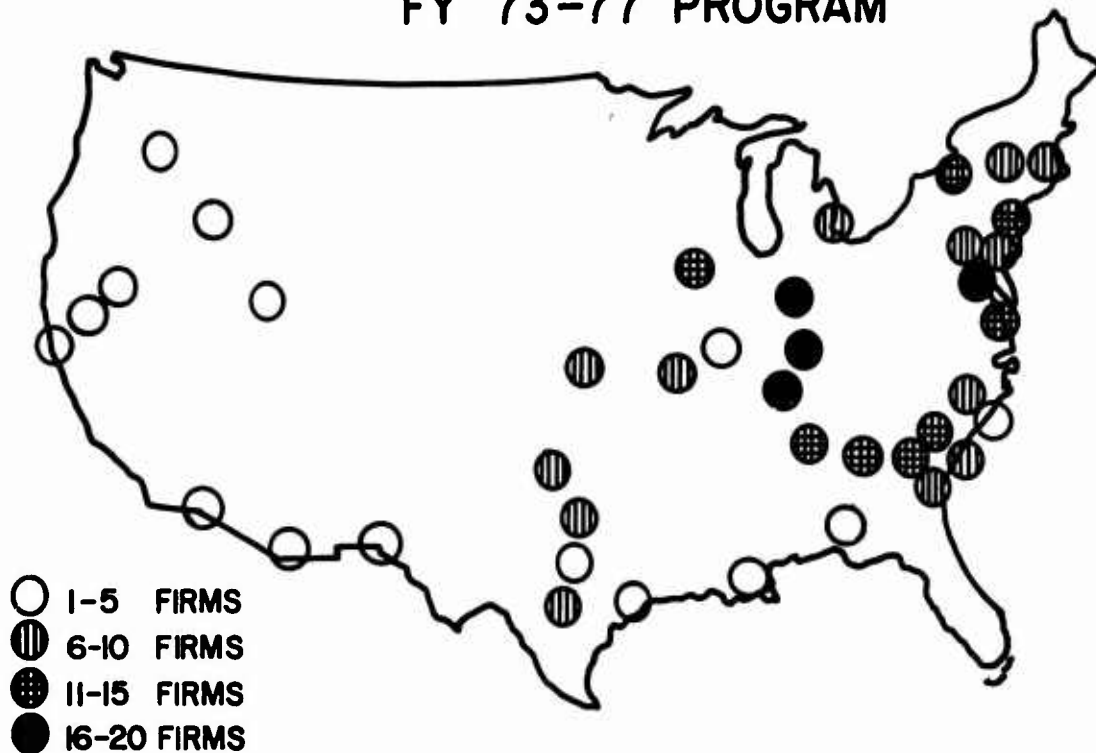


FIGURE 5

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Construction Engineering Research Laboratory P. O. Box 4005 Champaign, Illinois 61820		2a. REPORT SECURITY CLASSIFICATION Unclassified	
3. REPORT TITLE INDUSTRIALIZED BUILDING for the Department of the Army		2b. GROUP	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final report in 3 volumes			
5. AUTHOR(S) (First name, middle initial, last name) Cpt. D. Gordon Bagby, Dr. Robert M. Dinnat, Christopher A. Moyer			
6. REPORT DATE August 1971		7a. TOTAL NO. OF PAGES 275	7b. NO. OF REFS 45
8a. CONTRACT OR GRANT NO. NAM-M-71-141 (DMC-OCE)		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO.			
c.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		AD number obtainable from CERL-RL	
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited			
11. SUPPLEMENTARY NOTES Use AD number to obtain copies of this report from National Technical Information Service, Springfield, Virginia 22151		12. SPONSORING MILITARY ACTIVITY Department of the Army	
13. ABSTRACT This study had six principal objectives: 1. To provide background information on the history, characteristics and direction of industrialized building; 2. To measure and document the present capabilities of the industrialized building; 3. To identify industrialized building systems suitable for employment in the Army's military construction program; 4. To suggest locations where industrialized building is likely to be most economical; 5. To identify and discuss possible procurement and implementation procedures; and 6. To provide comparisons between conventional and industrialized construction costs and construction durations. Only 24 firms within the continental United States evidenced the requisite design, procurement policies, and production capabilities to meet immediate military construction needs. An additional 25 firm products were suitable for use in selected building types in particular geographical regions. Secondly, joint purchasing consortiums with some civilian agencies proximate to military installations are possible during the intermediate range MCA Program. Thirdly, although cost comparisons with conventional construction proved inconclusive, substantial construction time will be saved.			
14. KEY WORDS Industrialized building; design, production, procurement, time			

DD FORM 1473
1 NOV 65REPLACES DD FORM 1473, 1 JAN 64, WHICH IS
OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

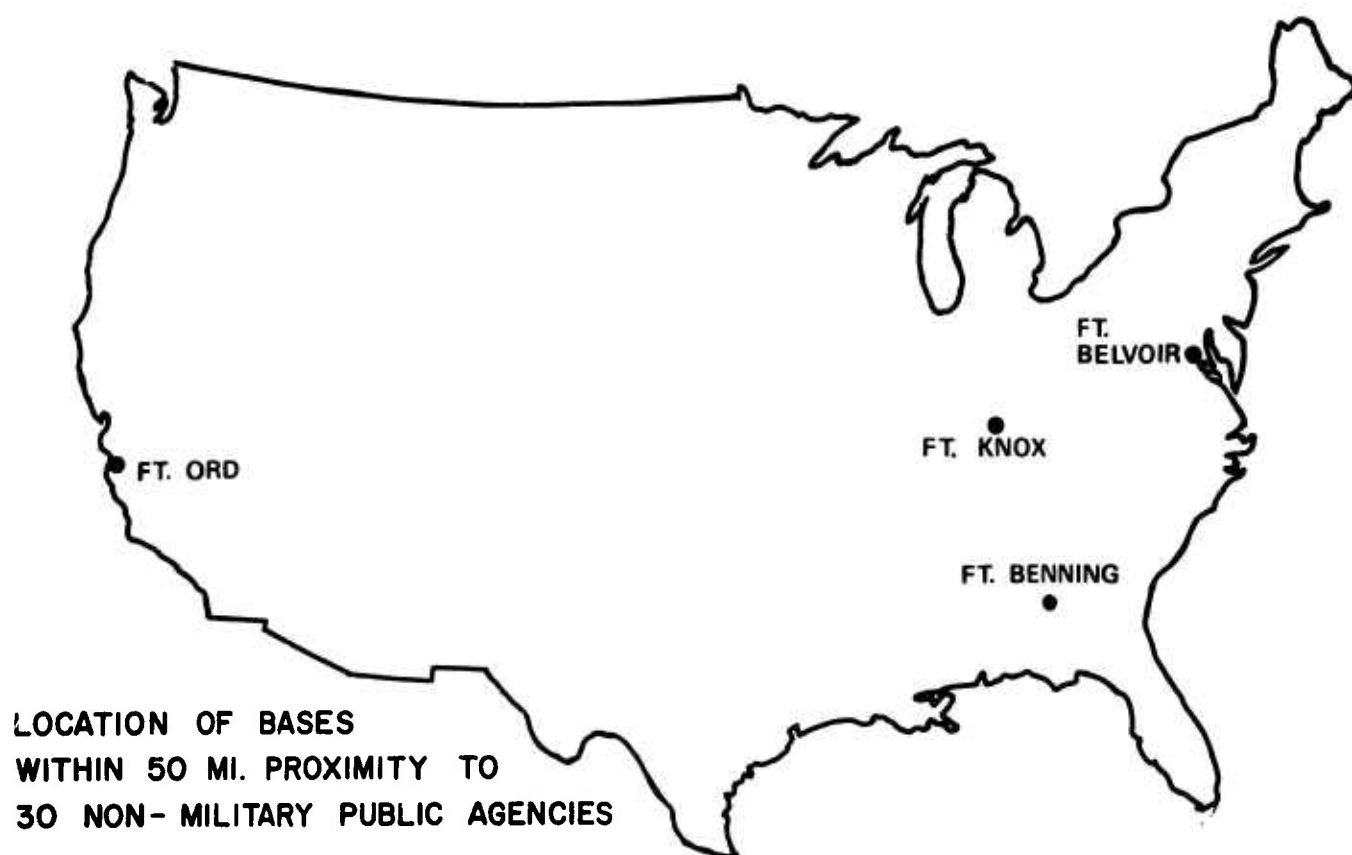


FIGURE 6

INITIAL COSTS: CONVENTIONAL VS. INDUSTRIAL

To acquire reliable data by which to compare initial costs of building types constructed by conventional and industrialized construction, a second survey which solicited cost information (together with detailed information on the characteristics of the buildings) was conducted with 100 respondents to the original questionnaire on industrialized building projects constructed in 1969, 1970 and 1971. Over 90 percent return was obtained to this second solicitation producing 89 usable pieces of data. Cost data on conventional construction of the last 10 years were collected from the Specifications and Estimating Branch of the Engineering Division within the Directorate of Military Construction of the Office of the Chief of Engineers. All data were adjusted to a common 1970 price level using the Engineering News Record's Construction Index.

These data were analyzed statistically to compare the cost for producing industrialized products to that of conventional construction. The industrialized building cost data made comparisons with conventional construction costs inconclusive, but the trend in the calculation indicated a lesser cost via conventional construction. The calculation indicated that the average cost of constructing three story barracks during the past six years has been 7.67 percent below the price which would have been experienced had the Corps chosen to utilize industrialized methods. Cost comparisons for Bachelor Officer Quarters indicated that constructing BOQ's with industrialized methods would cost 14.3 percent more than conventional construction while constructing maintenance and repair facilities with industrialized products, would probably cost the government 70 percent more than the conventional construction.

LIFECYCLE COSTS: CONVENTIONAL VS. INDUSTRIALIZED

Since initial costs constitute only a fraction of the total expenditures over the lifetime of a facility, an investigation was made to identify and categorize the cost factors to be used in estimating comparative lifetime costs of industrialized building facilities.

CONSTRUCTION TIME: CONVENTIONAL VS. INDUSTRIAL

Statistical analyses of construction time of conventional versus industrialized building suggested that projects requiring one year to construct with conventional techniques would require only four months using industrialized building techniques, while more complex conventional projects of two year's duration would require slightly less than six months of time to construct with industrialized components.

INDUSTRIALIZED BUILDING PRICE INDICES

Finally, various regression analyses suggested that significant seasonality and geographical price variations characterize the current industrialized construction industry, and that industrialized building prices have risen at the same rate experienced by current conventional construction over the past ten years.

SUMMARY

Several conclusions corresponding to the original study objectives emerge from this study. In general the U. S. industrialized building industry appears capable of meeting current Department of the Army military installation needs. The geographical localities best served by this industry include the Mid-Western and Atlantic seaboard regions of the United States.

Although current industrialized building construction costs appear to exceed costs experienced with conventional construction, technological improvements and competition within the industrialized building industry warrant an optimistic long term prognosis.